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50X1-HUM

AN "EXTREMAL" PROBLEM ON THE USE OF SELECTORS IN COMPUTING-ANALYTICAL MACHINES

I. Ya. Akushskiy

The operating principle and some uses of selectors were cited in I. Ya. Akushskiy's two articles, "Computing-Analytical Machines and Some of Their Applications to Mathematical Problems" (Uspekhi Matematicheskiy Nauk, Vol II, No 2, 1947) and "The Process of Diagonal Summation on a Tabulator and Some of Its Applications" (Izvestiya Akademii Nauk SSSR, Otdeleniye Tekhnicheskikh Nauk, No 5, 1947). In this article, we consider in more detail some problems in the utilization of selectors and formulate the basic problem involved in the use of selectors to carry out calculations on computing-analytical machines.

The selectors are designated by $S_1, S_2, \ldots, S_v$; The middle contacts of the selector elements are designated by C_w^n, where w is the selector number and n is the number of the element (groups of three contacts, the middle one of which is given) in the selector S_w. The other two contacts are designated, respectively, $(x)_w^n$ and $(Nx)_w^n$. Each selector S_w has its own control contact ξ_w. There are two possible positions for the contacts of the selector S_w: (1) C_w-$(Nx)_w$, when all elements (independent of the number n) of this selector are in the position C-(Nx), i.e., the middle contacts C^n of all elements are connected with the contacts $(x)_w^n$ of their elements, and (2) C_w-$(x)_w$, when the contacts C_w^n are connected with the contacts $(x)_w^n$ of their elements. Position 1 or 2 occurs simultaneously for all elements of S_w.

The position of selector S_w is determined by the input or noninput of a current pulse on control contact ξ_w. The input of a pulse on ξ_w drives S_w into position 2, while the absence of a pulse on ξ_w leaves S_w in position 1.

We will not consider the operation of selectors as they are used in the transmission of pulses from punch cards. As in the works mentioned above, we will designate the punch cards by P with the corresponding subscripts and counters by σ, the counters also differing in the subscripts. In this type of selector operation, position 1 or 2 of selector S_w in the process of passing a card P_i is regulated by the absence or presence of a punch (perforation of the 11th position) along a certain column λ_w, which, being connected with control contact ξ_w, sends it a pulse if there is a punch and leaves it unexcited if there is no punch along column λ_w.

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We designate by g_j the j-th section of the punch card, i.e., the group of columns in which the homogeneous components of the calculation are punched out. In order that the number punched in section g_j be registered in counter σ_k, the columns of section g_j (block B_2) must be connected (maintaining correspondence of division) to the electromagnets of the number wheels of counter σ_k. We will designate this connection by $g_j \rightarrow \sigma_k$. This connection ensures that the numbers punched in section g_j of all cards which are passed through block B_2 will be registered on counter σ_k.

The number of sections g_j is limited by the capacity of the punch cards in dependence upon the "valence" of the numbers punched in g_j. The connection $g_j \rightarrow \sigma_k$, as we have already pointed out, sends into σ_k the numbers punched in g_j from all cards which pass through block B_2. Very often, however, in the process of passing a group of cards, the required direction, or control, of the data on the card sections in the counter for different cards is not covered by this connection. In these cases, selectors are used to introduce the necessary differentiation in the control of data in the counters in dependence on the card type.

Let us consider the distributing operation of a selector, given m cards P_1, $P_2, \ldots, P_m$. In the g section of these cards, numbers are punched which must be directed into different counters, i.e., from card P_1 into σ_1, from card P_2 to σ_2, from card P_m into σ_m. It is easy to see that the required direction of data cannot be accomplished by any one direct connection of g with σ_i. We make the following connection by means of selectors:

$$g \rightarrow C_1,\ (Nx)_1 \rightarrow C_2,\ (x)_1 \rightarrow C_3,\ (Nx)_2 \rightarrow C_4,\ (x)_2 \rightarrow C_5,\ (Nx)_3 \rightarrow C_6,\ (x)_3 \rightarrow C_7$$
$$\ldots,\ (Nx)_q \rightarrow C_{p-1},\ (x)_q \rightarrow C_p;$$
$$(Nx)_{q+1} \rightarrow \sigma_1,\ (x)_{q+1} \rightarrow \sigma_2,\ (Nx)_{q+2} \rightarrow \sigma_3,\ (x)_{q+2} \rightarrow \sigma_4,\ \ldots.$$
$$\ldots,\ (Nx)_p \rightarrow \sigma_{m-1},\ (x)_p \rightarrow \sigma_m.$$

The numbers p and q are determined from the following considerations: $p-q = [m/2]$, $q = [m/2]-1$. The control contacts of selectors $\varepsilon_1, \varepsilon_2, \ldots \varepsilon_p$ must be connected with columns $\lambda_1, \lambda_2, \ldots, \lambda_p$, in which we introduce a system of punches, different for different cards. Thus, card P_1 must not have a punch in any of the columns λ_1, $\lambda_2, \ldots \lambda_p$; card P_2 must have a punch in column λ_{q+1}, etc. In general, the control columns and the system of punches may be introduced by different methods, with the restriction, however, that in the passage of card P_1 all selectors should occupy positions which will, in the final analysis, create the circuit $g \rightarrow \sigma_1$.

We have discussed the distribution problem for m different cards, but our considerations would have been no different had we discussed m different groups of cards $\mu_1, \mu_2, \ldots, \mu_m$, where a definite direction of the g section into the counter must occur for all cards of the given group. In this case, all cards of group μ_i must have the system of punches which in the case previously discussed was imposed on P_1. Therefore, in the future we will discuss individual cards of various types rather than groups of cards.

The collection operation as it is usually understood is opposite to the distribution operation. Given m cards $P_1, P_2, \ldots, P_m$ with m sections $g_1, g_2, \ldots, g_m$ in each card. The numbers punched in these sections must be directed into counter σ; moreover, a number from section g_1 from card P_1, a number from section g_2 from card $P_2, \ldots$, a number from section g_m from card P_m, must be directed into σ.

50X1-HUM

It can be shown that any commutation solving the distribution problem (with respect to the distribution of one section in m counters) can be used to solve its corresponding collection problem with respect to the collection in one counter of data from m sections (by simply substituting g for σ, and vice versa, in the commutation series and changing the direction of the arrows). Thus, from the preceding commutation, we can write the solution of the collection problem in the following way:

$$\sigma \leftarrow C_1,\ (Nx)_1 \leftarrow C_2,\ (x)_1 \leftarrow C_3,\ (Nx)_2 \leftarrow C_4,\ (x)_2 \leftarrow C_5,\ (Nx)_3 \leftarrow C_6,\ (x)_3 \leftarrow C_7, \ldots$$
$$\ldots, (Nx)_q \leftarrow C_{p-1}, (x)_q \leftarrow C_p;$$
$$(Nx)_{q+1} \leftarrow g_1,\ (x)_{q+1} \leftarrow g_2,\ (Nx)_{q+2} \leftarrow g_3,\ (x)_{q+2} \leftarrow g_4, \ldots\ldots$$
$$\ldots, (Nx)_p \leftarrow g_{m-1}, (x)_p \leftarrow g_m.$$

Commutation of the control contacts of the selectors and the system of punches on each card are the same as they were in the distribution problem.

The distribution and collection problems discussed are partial cases of the following general problem.

Given m! cards $P_1, P_2, \ldots, P_{m!}$ with m sections in each card, and let m counters $\sigma 1, \sigma 2, \ldots, \sigma m$ participate in the operation. There are m! possible combinations of the distribution of sections $g_1, g_2, \ldots, g_m$ with respect to counters $\sigma 1, \sigma 2, \ldots, \sigma m$. For each card P_i, one of these combinations must occur. What is the minimum number of selectors needed to accomplish all required distributions? What is the combination through these selectors? What is the system of controlling punches which must be imposed on each card?

We consider one of the possible commutations for solution of this general problem. Let m groups of selectors S_w^a (w is the number of the selector and a is the number of the group) participate, with m-1 selectors in each group.

We make the following connections:

$$g_1 \rightarrow C_1^1,\ (Nx)_1^1 \rightarrow C_2^1,\ (Nx)_2^1 \rightarrow C_3^1, \ldots\ldots, (Nx)_{m-2}^1 \rightarrow C_{m-1}^1$$

$$g_m \rightarrow C_1^m,\ (Nx)_1^m \rightarrow C_2^m,\ (Nx)_2^m \rightarrow C_3^m, \ldots\ldots, (Nx)_{m-2}^m \rightarrow C_{m-1}^m$$

$$(x)_1^1 \rightarrow \sigma_1,\ (x)_2^1 \rightarrow \sigma_2, \ldots, (x)_{m-1}^1 \rightarrow \sigma_{m-1},\ (Nx)_{m-1}^1 \rightarrow \sigma_m,$$

....

$$(x)_1^m \rightarrow \sigma_1,\ (x)_2^m \rightarrow \sigma_2, \ldots, (x)_{m-1}^m \rightarrow \sigma_{m-1},\ (Nx)_{m-1}^m \rightarrow \sigma_m.$$

Here (m-1)m selectors S_w^a are occupied. The direction $g_a \rightarrow \sigma_w$ is accomplished by simultaneously positioning the selectors $S_1^a, S_2^a, \ldots, S_{w-1}^a$ at C-(Nx) and the selector S_w at C-(x) (if $w \neq m$), or C-(Nx) (if $w = m$). Thus, the connection $g_a \rightarrow \sigma_w$ will be made for cards supplied with a punch along the column λ_w^a (for $w \neq m$). The connection $g_a \rightarrow \sigma_m$ will be made for cards which do not have punches in any of the columns $\lambda_1^a, \lambda_2^a, \ldots\ldots, \lambda_{m-1}^a$ (presupposing that the control contact ζ_w^a of selector S_w^a is connected with column λ_w^a). Thus, it results that if for a card P_ν, directions in the counters $g_1 \rightarrow \sigma\nu_1$, $g_2 \rightarrow \sigma\nu_2, \ldots, g_m \rightarrow \sigma\nu_m$ ($\nu_1 \nu_2, \ldots, \nu_m$ are any combinations of the numbers 1, 2, ..., m) must be accomplished, then the card P_ν must have punches in all those columns $\lambda_{\nu 1}^1, \lambda_{\nu 2}^2, \ldots, \lambda_{\nu m}^m$, in which the lower subscript is not equal to m.

50X1-HUM

We have introduced this commutation only to illustrate one possible method of solving the general problem of selector operation and are in no way suggesting that the number of m(m-1) selectors is the least possible to make the required distributions. At the same time, the "extremal" problem formulated above is of great importance.

The growing practice of using computing-analytical machines for mathematical problems requires very complex commutations with the associated high number of selectors, but there is only a limited number of these selectors in the machine.

Therefore, it is very important: (1) to have a regular method for economic utilization of the selectors when making up various commutation arrangements and (2) to be confident, when there are not enough selectors in the machine to accomplish an arrangement, that the arrangement is in principle not realizable for the given number of counters and that its unrealizability is not the result of an unimaginative arrangement.

These are the considerations behind the problem formulated above.

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